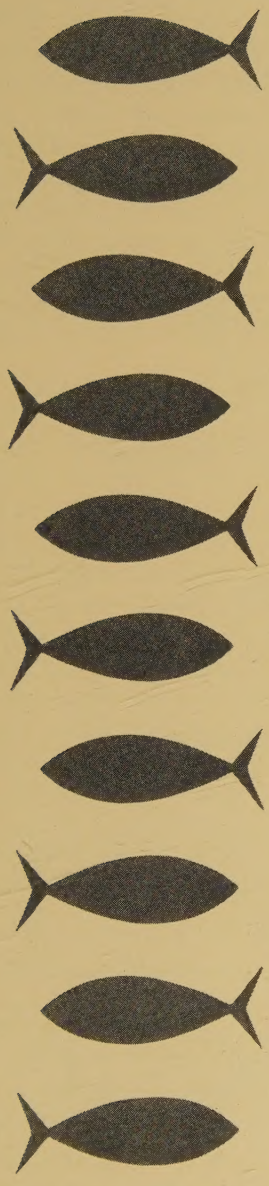
Southwest
FISHERIES SCIENCE CENTER

HONOLULU LA JOLLA MONTEREY TIBURON

REPORT OF ACTIVITIES July-August 1993



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CENTER ADMINISTRATION- La Jolla, California

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Deputy Director ..... *Richard A. Neal*
Planning Officer ..... *David J. Mackett*
Information Technology Services ..... *Dorothy Roll*
Executive Officer ..... *Sherrie L. Rasmussen*

LABORATORIES & DIVISIONS

Antarctic Ecosystem Research Group, Chief ..... *Rennie Holt*
La Jolla, California
Coastal Fisheries Resources Division, Chief ..... *John R. Hunter*
La Jolla, California
Marine Mammal Division, Chief ..... *Robert L. Brownell, Jr.*
La Jolla, California
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Honolulu, Hawaii
Pacific Fisheries Environmental Group, Chief ..... *Vacant*
Monterey, California
Pelagic Fisheries Resources Division, Chief ..... *Gary T. Sakagawa*
La Jolla, California
Tiburon Laboratory, Director ..... *Alec MacCall*
Tiburon, California

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ANTARCTIC ECOSYSTEM RESEARCH GROUP

La Jolla, California

WG-Krill and WG-CEMP Meetings Held

Meeting of the WG-KRILL. The Scientific Committee (SC) of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) has established a permanent Working Group on Krill (WG-Krill) that meets each year to discuss pertinent krill management issues and subsequently prepares a report for the use of the SC and ultimately the Commission of CCAMLR. The fifth meeting of WG-Krill was held in Tokyo, Japan, from August 4 to 12, 1993. Members of CCAMLR nominate specialists to participate in the Working Group; attending for the United States were Antarctic Ecosystem Research Group's Chief Rennie Holt and Fishery Biologist Roger Hewitt and John Bengtson, National Marine Mammal Laboratory.

During last year's meetings, the SC identified the following topics as having the highest priority for consideration at the 1993 WG-Krill meeting: (1) continued investigation of the movement of krill (also known as krill flux) in and out of, as well as within, the previously defined CCAMLR Statistical Areas (of particular interest was Statistical Area 48, which covers the Atlantic sector of the convention area); (2) estimation of the total effective krill biomass in the statistical subareas; (3) estimation, refinement, and validation of methods to calculate potential yield and precautionary catch limits of krill in various statistical areas and subareas; (4) work on models to describe functional relationships between krill, krill predators, and the krill fishery; and (5) work on estimating the possible extent of krill mortality during fishing operations.

Four members of CCAMLR (Russia, Japan, Poland, and Chile) indicated that they operated commercial fisheries for krill in the convention area. The total krill catch for the season was 81,394 metric tons (t), which is substantially less than the total catch in the 1991/92 season (302,961 t), and is well below the precautionary catch limit of 1.5 million t. The lower total catch was mainly due to reduced fishing efforts by Russia (only 2,998 t) and no fishing by the Ukraine, both of which resulted from the political reorganization of the former U.S.S.R. Both Russia and the Ukraine plan to conduct krill fishing next season. Japan had the largest catch of 59,271 t, from five fishing vessels, and announced their intention to maintain a comparably sized fishery next season. Poland's catch of 15,623 t was double that of last season; the Working Group agreed that details of future Polish fishing plans should be obtained. Australia is still considering an application to harvest krill, but legal and financial delays indicate this venture is unlikely to proceed during 1993/94. The Working Group noted press reports indicating India's interest in entering the krill fishery.

Roger Hewitt, along with Chilean scientist Victor Marin, presented preliminary results of a joint U.S.-Chilean study that attempted to merge U.S. acoustic survey data from around the Elephant Island area of Antarctica (collected during the 1992 AMLR cruise) with Chilean krill fishery data from the same area. The collaboration was the result of questions posed at previous CCAMLR meetings regarding the possibility, and subsequent utility, of creating a Composite Index of Krill Abundance from these two data sets to derive better catch-per-unit effort indices for krill. The results indicate that some of the parameters required for the Composite Index, such as the characteristic radius of krill concentrations, are extremely difficult to estimate. Furthermore, the U.S. acoustic survey data have intense temporal variability, and this has the potential of confounding combined analyses of fisheries and acoustic survey data, which are not collected simultaneously. Hewitt will table a paper presenting the final results of the study at the upcoming meeting of the CCAMLR SC in October.

A significant amount of meeting time was devoted to the discussions of krill flux. At its 1991 meeting, the Working Group identified the need for hydrographic data which might be used to indicate possible immigration and emigration rates and retention times of krill in the various fishing grounds and statistical subareas. Several papers containing relevant information gathered from experiments with drifting buoys and geostrophic flow calculations allowed this year's Working Group to produce a table summarizing information on possible water movements between subareas. All agreed that much work is needed in this area, and a special workshop was planned for next year to study how much time krill reside in different fishing grounds and statistical subareas.

At the meeting, SWFSC's Hewitt and Ocean Acoustics Engineer David Demer presented a paper titled "Bias in acoustic biomass estimates of *Euphausia superba* due to diel vertical migration." The pa-

per discusses five acoustic surveys, conducted during the AMLR 1992 cruise around Elephant Island, in which krill were observed to be dispersed in the upper portion of the water column at night but were more concentrated and deeper during the day. The paper suggests that this diel vertical migration may result in a bias to krill biomass estimates because substantial numbers of krill may physically be above the downlooking towed acoustic array during dark hours. Hewitt and Demer constructed a polynomial function to fit the data to account for this bias; the resulting biomass estimates were 2.3 to 99.6 percent higher than those disregarding bias due to diel vertical migration.

Annual acoustic estimates of krill biomass in the Elephant Island area for the years 1981 through 1993 were presented in another paper written by Hewitt and Demer. Survey results prior to 1992 were adjusted to consider the new definition of krill target strength formulated at the 1991 meeting of WG-Krill. Their paper showed average areal krill biomass densities in the area for January to March of every year during the 1981-1993 period except 1982, 1983, and 1986. It also gave a qualitative evaluation of krill recruitment. In six out of seven cases, good (or bad) krill recruitment corresponded to an increase (or decrease) in krill density the following year.

Valerie Loeb, Moss Landing Marine Laboratory, and Volker Siegel, Sea Fisheries Institute, authored a paper titled "Status of the Krill Stock around Elephant Island in 1991/92 and 1992/93," which was presented at the meeting. In the paper, they present data collected as part of the AMLR program and highlight some interesting aspects of krill dynamics. The relatively long time series of data indicates that distribution of krill by maturity stage is quite consistent from year to year. There is some evidence that recruitment success may depend on the maturity stage of females at a specific time of year.

The Working Group devoted some time to the issues of salp abundance and demography; salps, *Salpa thompsoni*, are a species of tunicate found in the Antarctic that may play a significant role in the pelagic ecosystem. Loeb and Siegel hypothesized in the above paper that the presence of salps may cause a reduction in the number of female krill in spawning condition compared to numbers observed when salps are absent. It was also noted that high salp abundance in a given year may lead to low krill recruitment in the following year. The Working Group concluded that further attention should be given to the demography of salps as well as to investigation of ways to distinguish salps from krill in acoustic survey data.

Finally, in planning for future work of the WG-Krill, the following points were highlighted: (1) continuing development of the model used to assess the potential yield of krill, (2) convening a workshop to evaluate krill flux in Statistical Area 48, and (3) implementing future surveys for krill abundance and distribution.

Meeting of WG-CEMP. Another group of specialists that meets annually is the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP). The CEMP is designed to detect significant changes in key components of the Southern Ocean ecosystem and to distinguish between changes due to commercial harvesting and those due to natural causes. This year's WG-CEMP meeting was held in Seoul, Republic of Korea, from August 16 to 23, 1993. Attending for the United States were Antarctic Ecosystem Research Group Chief Rennie Holt, John Bengtson and Peter Boveng from the National Marine Mammal Laboratory, Polly Penhale from the National Science Foundation, and Wayne Trivelpiece from Montana State University.

The basic objectives of the CEMP are (1) to prevent decrease in the size of any harvested population to levels below those which ensure its stable recruitment; (2) to maintain the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources, and the restoration of depleted populations; and (3) to prevent changes or minimization of the risk of changes in the marine ecosystem which are not reversible over two or three decades. Clearly, it would not be practical to attempt to monitor all organisms and their interactions in order to support these objectives. Instead, CEMP participants have identified key prey and predator species and specific parameters likely to be particularly sensitive to changes in food availability. These indicator species and parameters are continuously monitored by participants, and results of the monitoring are discussed at WG-CEMP for formulation of advice to the CCAMLR SC.

The CEMP has also identified specific sites in the Antarctic for these monitoring studies; the CEMP sites are chosen primarily because of their proximity to existing fishing grounds, the presence of selected predators, and the existence of current or

prospective long-term research programs. At this year's meeting, the delegations of the United States and Chile submitted a draft management plan for the protection of a new CEMP site at Cape Shirreff and the San Telmo Islands, in the South Shetland Islands, at the tip of the Antarctic Peninsula. Subject to some minor editorial changes, the Working Group recommended that the plan should be submitted to the SC.

One of the main topics at this year's meeting was the potential impact of localized krill catches on krill predators. In recent years, it has become increasingly apparent that there is a consistent pattern of temporal and spatial overlap between krill harvesting and feeding by land-based predators in Statistical Subareas 48.1 and 48.2 during the predators' breeding seasons. This situation led to CEMP's recognizing that further work is needed to more precisely investigate this overlap and to more accurately assess the magnitude of potential competition between predators and the krill fishery.

Another issue discussed at this year's WG-CEMP meeting was the use of data collected with Time Depth Recorders (TDRs) for studies involving foraging performance of krill predators (penguins and seals). Several papers were tabled that presented various TDR data, and after discussion, the Working Group decided that WG-CEMP should try to develop its own set of guidelines and methods for the use of TDRs to provide standardized sets of data which could be used to derive indices of diving and/or foraging performance. Variables that might be relevant in a consideration of potential indices include duration of foraging trip, time spent in searching and feeding, number of diving bouts, duration of bouts, and dive characteristics—such as depth. The Working Group agreed to address this topic during an intersessional exchange of information, to review the topic at its next meeting, and then to decide whether or not it would be appropriate to hold a workshop on the topic, ideally in 1995. Boveng agreed to organize the exchange of information.

Finally, the WG-CEMP noted that there are numerous topics of common interest to the WG-CEMP and the WG-Krill, in particular, efforts to model the functional relationships between predator performance and krill availability. Thus, the Working Group is planning a joint WG-Krill and WG-CEMP meeting to discuss such topics. (J. Rosenberg, [619] 546-5600)

COASTAL FISHERIES RESOURCES DIVISION

La Jolla, California

Research on Effects of Oxygen Minimum Zone on Fish Production

The Dover sole, *Microstomus pacificus*, is an important commercial fish species which occurs in Pacific coastal waters from off Alaska south to Baja California. Annual landings between 1982 and 1989 were generally higher than for any other inshore groundfish, averaging about 19,000 metric tons per year. This benthic species makes a vertical migration from shallow water when young to deeper levels as it matures. It can move into water as deep as 1200 m; however, most Dover sole off the coast of California occur in the Oxygen Minimum Zone (OMZ, 400-800 m) where oxygen concentrations are as low as 0.30-0.50 mg/L. The muscle of these large adult fish has very high water content ("jellied condition") and, as a result, large fish are not as marketable as the younger shallow-water individuals. The reasons for the high water and low energy content of large fish are not entirely clear; however, it is thought that one contributing factor is the severe hypoxic (low oxygen) conditions of the OMZ. Studies by National Research Council Fellow Edward Goolish, Fishery Biologist Eric Lynn, Fishery Biologist Larry Robertson, and Research Physiologist Russ Vetter of the Genetics and Physiology Laboratory are being completed on the effects of low oxygen on the metabolism and bioenergetics of Dover sole. Electronics Technician Matt Bones has also contributed his electronic expertise to the design of a tank system for maintaining experimental fish under low oxygen conditions.

When acclimated to low oxygen conditions (0.50 mg/L), similar to that which occurs in the OMZ, Dover sole make many physiological adjustments to increase the rate at which they can take up and deliver oxygen. Their concentration of red blood cells (hematocrit), the affinity of their blood for oxygen, and the relative size of their gill tissue all increase after just 8 weeks of acclimation. These changes do not appear to provide enough compensation, however, because other data indicate that the metabolic rate of hypoxic fish is much lower than for fish maintained at a high-oxygen concentration. Hypoxic fish have smaller hearts, lower white muscle citrate synthase activity (an aerobic enzyme), and they lose only one-fifth as much weight as control fish when maintained without

food for 8 weeks. The hypoxic conditions of the OMZ may also limit Dover sole metabolism indirectly by limiting the rate at which food can be processed. Dover sole maintained under hypoxic conditions and given excess food rations consume only 50 percent as much food as those which are held at a high oxygen concentration. Because of their lower metabolic rate, however, hypoxic fish are able to grow at the same or at a higher rate as fish under high oxygen conditions (Fig. 1). These results, which suggest that the hypoxic condition of the OMZ is influencing the feeding, growth, and production of the Dover sole, have many implications for population-level dynamics. For example, population-level growth rates may not be density dependent, as is sometimes assumed, if food consumption rates are determined more by oxygen concentration than by food density.

Laboratory experiments to determine the lower limits of oxygen tolerance for the Dover sole have also been completed. This information will be useful for understanding the geographic distribution of Dover sole with regard to the OMZ. Dover sole acclimated in the laboratory for 8 months to high oxygen (≥7.00 mg/L) are still remarkably tolerant of hypoxic conditions (Fig. 2). When exposed to oxygen concentrations decreasing from 1.00 to 0.08 mg/L over a 4-day period, these fish survive to a mean oxygen concentration of 0.23 mg/L, a value which is generally lower than that occurring in the OMZ. If Dover sole are first allowed to acclimate to low oxygen (8 weeks at 0.50 mg/L), they can survive down to a mean oxygen concentration of just 0.08 mg/L, with fed fish surviving significantly longer than those which are starved. A chapter has been prepared for the new series *The Biochemistry and Molecular Biology of Fishes* (P. W. Hochachka and T. P. Mommsen, editors) which reviews some of these results as well as those obtained from Dover sole in the OMZ.

Young Dover sole occur in the shallow water of the Continental Shelf, which has a relatively high concentration of oxygen. As individuals become

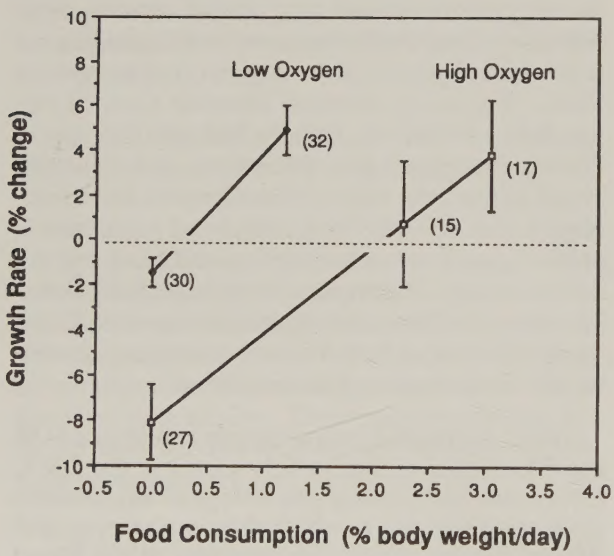

Figure 1. Whole body growth rates ($\bar{x}$ ± standard error) of individual Dover sole, *Microstomus pacificus*, at various rates of food consumption. The growth rate of Dover sole, at a given ration size, is much higher when maintained under low oxygen conditions (0.50 mg O_2/L; •) than when exposed to high oxygen conditions (≥7.00 mg O_2/L; ❑). Growth is expressed as the percent change of initial wet weight over an 8-week period. Sample sizes are indicated in parentheses.

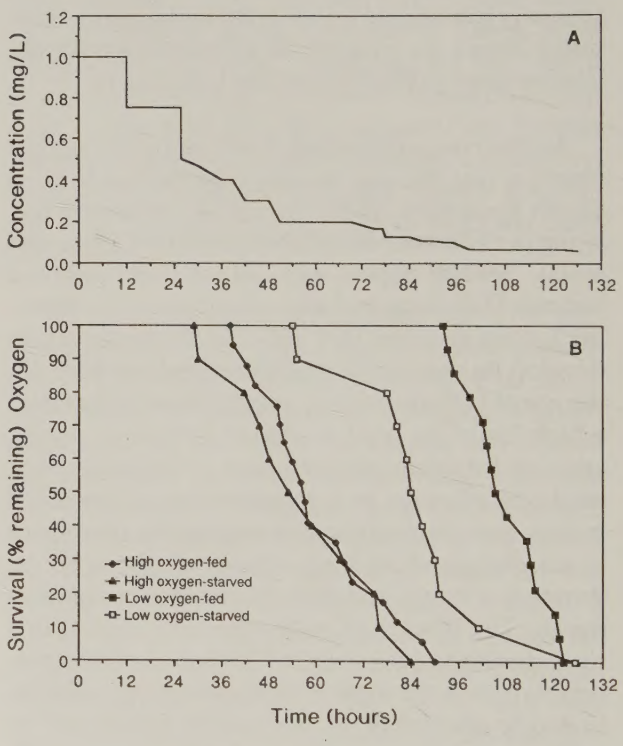

Figure 2. Variance in hypoxia tolerance among individual Dover sole. (A) Rate of decline in oxygen concentration experienced simultaneously by all treatment groups over a 5-day period. (B) Survivorship curves for Dover sole during the 5-day study period in (A). Previous to the 5-day period, the four groups of Dover sole were acclimated for 8 weeks to high oxygen and fed (≥7.00 mg/L; ♦), high oxygen and starved (▲), low oxygen and fed (0.05 mg/L; ■), and low oxygen and starved (❑). Each symbol represents the time of death for an individual Dover sole.

older and larger, they migrate over a period of decades into the deeper water of the OMZ, where oxygen concentrations are as low as 0.30 mg/L. The physiological and metabolic adaptations which make this migration possible, therefore, were thought to require a very long period of time. The results of these studies suggest, however, that the factors which are most important for hypoxic survival are also those which can be altered relatively quickly. The changes which occurred in just 8 weeks for blood oxygen affinity (P_{50}), hematocrit, and relative gill size were large enough to affect survival and allow individuals to tolerate oxygen concentrations as low as 0.08 mg/L. These respiratory characteristics, therefore, are apparently not the factors which are limiting the long duration of the Dover soles' vertical migration. Most Dover sole are harvested near the OMZ, where oxygen concentrations are still relatively low (1-2 mg/L). The information obtained from these laboratory studies suggest that if these populations were depleted, shallow-water, high-oxygen fish could recolonize the area in a short time. However, although new immigrants may be able to survive in the OMZ, a much longer period of time seems to be required for the Dover sole to show a decrease in muscle energy content. It is not known how this transition would affect their bioenergetics. Muscle and ovary tissues, both sampled from the same individuals, have recently been collected. When analyzed for enzyme activity and egg production, these samples may provide further information on the relationship between metabolism and reproduction in Dover sole. (E. Goolish, [619] 546-7108)

Harmful Algal Bloom Workshop Held

A highly successful Harmful Algal Bloom Workshop was held at the La Jolla Laboratory August 17-19. The workshop was hosted by the NOAA CoastWatch West Coast Regional Node and the La Jolla Laboratory Coastal Fisheries Resources Division. The objectives of the workshop were (1) to provide information and training on the use of satellite data products available through CoastWatch and (2) to evaluate the feasibility of modeling marine environmental conditions necessary for the development of harmful algal blooms (HAB) along the west coast, with the goal of developing capabilities for identifying potential areas and times of where and when HAB may occur. The term "HAB" includes dinoflagellates (protists) and diatoms.

Topics addressed at the workshop were (1) HAB monitoring and research activities conducted by federal and state agencies and universities along the west coast, (2) environmental conditions associated with outbreaks of HAB, (3) satellite and in situ oceanographic data available on the west coast, (4) training in the use of software available from CoastWatch for displaying and analyzing satellite images, (5) experience in the Gulf of Maine HAB research using CoastWatch satellite imagery, and (6) potential for modeling.

Attendees of the workshop concluded that (1) biotoxin accumulations in shellfish, and sometimes finfish, result from algal blooms occurring in near-coastal waters or estuaries in central and northern California, Oregon, and Washington, but very rarely off southern California, (2) HABs are an important public health problem and have significant economic impacts on the west coast, (3) a multi-disciplinary approach in HAB research and monitoring will be required to make significant advances in understanding and modeling HAB, (4) ocean advection processes associated with coastal upwelling frontal structure and river plumes may be influential in triggering HABs in open coastal areas along the west coast, (5) local wind conditions may be important in setting up ecological conditions favorable for HABs in Puget Sound and similar estuaries on the west coast, (6) advanced, very high resolution radiometer satellite imagery, as well as measurements of ocean color from the SeaWiFS (National Aeronautic and Space Administration's sea-viewing, wide-field-of-view sensor) satellite to be launched in the summer of 1994, can provide much-needed environmental data related to HABs, (7) there appears to be adequate near-real time, in situ oceanographic information from moored ocean buoys and shore stations and from NOAA and Navy operational oceanographic numeric models for use in HAB monitoring and research on the west coast, but the information is difficult to access, (8) state agencies will begin using CoastWatch satellite data products in HAB monitoring activities, and (9) case studies should be undertaken to develop the understanding needed for maximizing the use of satellite imagery in monitoring for HABs and to obtain information required for modeling feasibility studies.

It was recommended that HAB case studies be conducted at Drake's Bay, California, and at Clatsop, Oregon. These are major problem locations for outbreaks of Paralytic Shellfish Poisoning (PSP), which is associated with HABs. Historical oceanographic data and satellite imagery collected concurrently with PSP events are also available in these two areas. It is envisioned that the case studies could be conducted collaboratively, with the West Coast CoastWatch Node providing satellite imagery and expertise and making arrangements for

the historical oceanographic data; the California Department of Health Services and the Oregon State Food and Dairy Division providing information on PSP biotoxins; and university scientists performing the studies. Sources of funding to conduct the case studies will be investigated.

There were 21 participants at the workshop from federal and state agencies and universities, including NOAA/NMFS, NOAA/NESDIS (National Environmental Satellite Data and Information Service), NOAA/NOS (National Ocean Service), U.S. Food and Drug Administration, California Department of Health Services, Oregon State Food and Dairy Division, University of California at San Diego, University of Washington, and Woods Hole Oceanographic Institution. (M. Laurs, [619] 546-7086)

MARINE MAMMAL DIVISION

La Jolla, California

DOLPHIN STOCK ASSESSMENT PROGRAM

1993 Common Dolphin Survey Launched

On July 28, 1993, two NOAA research vessels, *David Starr Jordan* and *McArthur*, departed from San Diego to conduct a 3-month survey of dolphins in the waters off Mexico and California. This year's survey is a cooperative effort between the United States and Mexico. The overall objective of this project is to survey the area inhabited by the northern stock of common dolphin in order to make an estimate of its absolute abundance and to further assess stock condition relative to dolphin mortality incurred in the international yellowfin tuna purse seine fishery in the eastern tropical Pacific (ETP). Because the tracklines for the survey cover a large portion of the area utilized by the high-seas driftnet fishery and California coastal setnet and driftnet fisheries, the Southwest Fisheries Science Center (SWFSC) will be able to collect valuable information on cetaceans which may be useful for management of these fisheries.

The United States Congress directed NMFS in 1984 to undertake these surveys, which were initiated by the SWFSC in 1986 after extensive planning and program review. Seven surveys have been completed to date: Monitoring of Porpoise Stocks (MOPS), 1986-1990; California Marine Mammal Survey (CAMMS), 1991; and Population of *Delphinus* Stocks (PODS), 1992. Using the MOPS data, no trends in abundance were detected although the power of the test statistic was low. Research vessel data are now also used to estimate minimum abundance for the purpose of setting absolute quotas on mortality for individual stocks as proposed by the Inter-American Tropical Tuna Commission (IATTC) resolution. The IATTC Resolution was adopted during a special meeting held in La Jolla, California, on April 21-23, 1992, to adopt a multilateral program to reduce and possibly eliminate dolphin mortality in the fishery. To date, reliable estimates of abundance have been made for most of the stocks of spotted, spinner, and striped dolphins; however, abundance estimates for common dolphins are not considered very reliable because of the limited sightings. The 1992 and 1993 PODS surveys have been designed to obtain these estimates.

During this year's PODS survey, SWFSC scientists are responsible for collecting information on the density, size, and species composition of marine mammal schools encountered off the Pacific coast of Mexico and California, and in the Gulf of California. The PODS survey is designed to collect data required to make minimum abundance estimates of cetacean stocks encountered, in particular, of the two forms (short-beaked and long-beaked) of the northern common dolphin, *Delphinus delphis*. Recent information indicates that the two forms are probably distinct species. In California, the distribution of both forms is likely to be continuous, with animals to the south along Baja California and possibly extended south into the ETP.

Physical, biological, and oceanographic data regarding the habitat of marine mammals inhabiting the ETP are also being collected to better understand marine mammal distributions. Aerial photographs of dolphin and tuna schools are taken from the helicopter aboard *Jordan* and are used to calibrate observer school size estimates as well as for species identification. Dolphin school vessel-avoidance studies are also conducted during these photogrammetric activities. On an opportunistic basis, aerial photographs of other cetaceans offer valuable information on distribution and movement of these species. Aerial photographs of pinniped colonies on coastal islands off the Pacific coast of Baja California and in the Gulf of California will be used to estimate the abundance of pinnipeds inhabiting Mexican waters. Photographic identification of dolphins and whales is conducted aboard both vessels. Tissue samples, using the biopsy dart method for genetic stock identification, are also

being collected aboard both vessels. And finally, because sea turtles may interact with tuna purse seine vessels, a number of projects have been designed to collect data on sea turtle distribution, movements, and general ecology in the ETP.

The first leg of the survey was completed as scheduled for both vessels. On August 18, *Jordan* entered port at Mazatlan, Mexico. *McArthur* entered port at Eureka, California. The second leg of the survey began on August 21. Both ships reached port in San Diego by September 12. The third leg was initiated on September 16.

During the third and fourth legs, *Jordan* will follow predetermined transects northward, returning to San Diego by November 2. *McArthur* will continue to follow predetermined transects southward within the study area and will return to Mexico where preparations will be made to initiate the second "Dolphin-Safe" survey. This survey will be a cooperative venture involving the IATTC, the academic community, and the fishing industry. Data from the PODS survey will be analyzed and the results will be presented for each vessel in a report by mid-1994. (J. Sisson, [619] 546-7064)

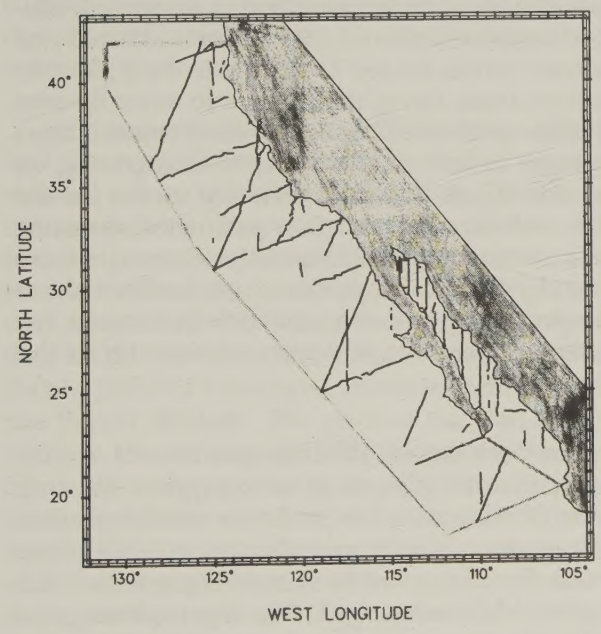

Figure 1. Tracklines followed by *David Starr Jordan* and *McArthur* on the first two legs of the 1993 Population of *Delphinus* Stocks survey. These tracklines cover the range inhabited by the northern stocks of common dolphin.

HONOLULU LABORATORY

Honolulu, Hawaii

PELAGIC RESOURCES INVESTIGATION

Study Shows Increase in Hawaiian Green Turtle Nesting Population

Green turtles in Hawaii are listed as a threatened species under the Endangered Species Act (ESA). Accordingly, an Interim Recovery Plan for Hawaiian Sea Turtles was developed by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USF&WS) that identifies critical needs for green turtle research and population monitoring. Under the plan, NMFS and USF&WS have jointly implemented a program to monitor green turtle nesting activity at East Island, French Frigate Shoals, where most nesting for the population takes place. The East Island surveys were established in 1973 by Marine Turtle Research Program Leader George Balazs. Each summer since then, a survey of green turtle nesting has been conducted at East Island, typically for a few weeks during peak nesting activity, and the data are used to estimate the year's total nesting population. Statistical estimation procedures were significantly improved following a recent 5-year series of saturation surveys at East Island, which covered the entire nesting season and provided detailed information about nightly turtle haulout probabilities (see *Southwest Fisheries Science Center Bimonthly Report of Activities*, September-October 1992). The new methods have been applied to historical nesting survey data by Pelagic Resources Investigation Chief Jerry Wetherall. Wetherall reestimated the nesting population for each of the past 20 years, 1973-92. A manuscript describing the study, coauthored by Wetherall and Balazs, has been completed and is under review for publication.

The revised estimates show a threefold increase in the number of green turtles nesting at East Island over the past 2 decades to an average of 240 nesters per year during the 1988-92 period (Fig. 1). Resurgence of the nesting population is likely a direct result of the full protection afforded Hawaiian green turtles under the ESA. Enacted in 1978, the ESA banned the taking of green turtles, which had long been exploited in Hawaii and were still vulnerable despite limited 1974 State of Hawaii regulations. Human activity still is a potential cause of

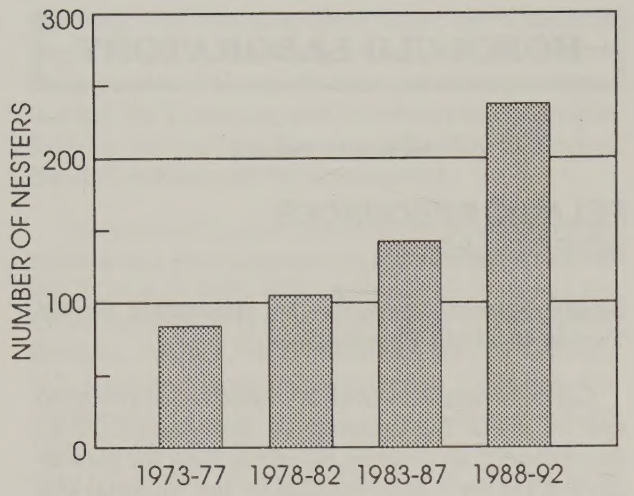

Figure 1. Average number of nesting green turtles at East Island, French Frigate Shoals, Northwestern Hawaiian Islands, based on annual nesting beach surveys.

green turtle mortality. For example, some Hawaiian green turtles are incidentally killed in fishing gear, including inshore gillnets and pelagic longlines. But the upward trend in the nesting population indicates that a significant reduction in mortality has been achieved under the ESA.

Although the 5-year averages clearly show that the nesting population is increasing, the number of nesters at East Island fluctuates considerably from year to year (the coefficient of variation within 5-year intervals is about 45 percent). Causes of the interannual variation are under investigation and likely include changes in the distribution of remigration intervals and the number of turtles recruiting to the nesting population. The relative importance of various factors is being investigated by analyzing tag resight data and detailed nesting survey statistics.

Monitoring trends in the nesting population is just one facet of the recovery plan for Hawaiian green turtles. Systematic inshore surveys are also under way, under Balazs' direction, to study populations of juvenile and subadult green turtles and their resting and foraging habitat and to understand factors affecting their survival. Extensive tagging of turtles has been carried out during these surveys. The tag resight data will be analyzed by Wetherall and Balazs during the coming year to assess the number of immature turtles. Continuation and expansion of the inshore surveys, combined with the nesting beach surveys at French Frigate Shoals, will provide a comprehensive basis for monitoring population recovery. (J. Wetherall, [808] 943-1258, and G. Balazs, [808] 943-1240)

Tracking Completed for Green Sea Turtles in Kaneohe Bay

Honolulu Laboratory Pelagic Ecosystem Program Leader Richard Brill, Marine Turtle Research Program Leader George Balaz, and Fishery Biologst Randolph Chang, along with Associate Researcher Kim Holland of the Hawaii Institute of Marine Biology (University of Hawaii), employed ultrasonic depth-sensitive transmitters to monitor the vertical and horizontal movements of juvenile green turtles, *Chelonia mydas*, in Kaneohe Bay, Oahu (Hawaii). This site was chosen because of its importance as a turtle foraging area and the high incidence (≈ 50 percent) of animals afflicted with fibropapillomas, a tumor disease of unknown etiology. The objectives of this study were to learn the movements, habitat use, and submergence intervals of this threatened marine turtle species and any effects tumors may have on these animals.

Both normal and tumor-afflicted turtles were found to remain within a restricted portion of the bay where coral patch reefs and shallow coral-covered areas are common. Both tumor-afflicted and normal turtles tended to remain in deep, muddy bottom areas during the day and to move up onto shallow patch reefs or shallow coral-covered areas at night (where they may have been grazing on benthic algae). It was known that turtles use the tops and sides of the shallow patch reefs as resting areas because they are frequently observed in these areas by divers. The extensive use turtles make of the deep, mud-bottomed channels in Kaneohe Bay as resting areas was, however, unknown before this study.

For both tumor-afflicted and normal turtles, more than 80 percent of submergence intervals were 30 minutes or less, and none was longer than 66 minutes. Juvenile green turtles in this environment, therefore, most likely maintain aerobic metabolism while submerged. The short submergence intervals are surprising given green sea turtles' well-known ability to be able to breath-hold for up to several hours. In Hawaii at least, green sea turtles do not routinely appear to exploit their remarkable physiological abilities. This finding may have important implications in those areas where turtle entanglement in fishing gear is a problem.

Tumor-afflicted turtles tended to have longer nighttime submergence intervals than normal turtles, which suggests that tumor-afflicted turtles are less active at night. The difference in submergence intervals was small, however. Intervals were shorter at night than during daylight in tumor-afflicted turtles. Normal turtles showed no such day-night difference. (R. Brill, [808] 943-1234)

PROTECTED SPECIES INVESTIGATION

Research Plan Completed for the Hawaiian Monk Seal at French Frigate Shoals

The number of births and beach counts of Hawaiian monk seals at French Frigate Shoals (FFS) was increasing during the 1980s. In 1990, a significant drop in births was observed at all monk seal breeding islands, but the births at sites other than FFS returned to expected levels the following year and remained at these levels. Births at FFS, however, have remained low through 1993. Beginning in 1991, high mortality of juvenile seals also became apparent at FFS, and this condition continues. These findings and observations (low growth rate of juvenile seals, low birth rate in adult females) suggest that the FFS population is near carrying capacity and is undergoing this decline because of reduced prey availability.

At its January 1993 meeting, the Hawaiian Monk Seal Recovery Team developed a list of recommended actions related to this problem. These recommendations, together with the monk seal knowledge and experience developed within the Marine Mammal Research Program (MMRP), were used to generate the "Research and Management Plan for the Hawaiian Monk Seal at French Frigate Shoals, 1993-96," Honolulu Laboratory Administrative Report H-93-08. The goals of the plan are to mitigate the demographic consequences to the monk seal of the apparent prey reduction and provide information necessary to monitor the adjustment of the population to its new resource base. In addition to population monitoring, the plan includes collecting, rehabilitating, and relocating young FFS females in poor condition to enhance their chance of survival to reproductive maturity; monitoring growth rates of young seals; doing disease surveys; and researching foraging patterns and prey preferences. This plan will guide MMRP activities at FFS during the next few years. (W. Gilmartin, [808] 943-1239)

FISHERY MANAGEMENT & PERFORMANCE INVESTIGATION

Charts Prepared for Longline Fishing in the Western Pacific

Staff from the Fishery Monitoring and Economics Program and the Pelagic Resources Investigation prepared 140 charts of Hawaii longline fishing effort and catch rates for the Western Pacific Regional Fishery Management Council. The charts record number of vessels, number of sets, number of hooks set, and catch rates for bigeye tuna, *Thunnus obesus;* blue marlin, *Makaira mazara;* swordfish, *Xiphias gladius;* and yellowfin tuna, *Thunnus albacares,* during 1991 and 1992 in 1-degree square increments of the 200-mile Exclusive Economic Zone (EEZ). Three seasonal increments were also charted, as were increments for small, medium, and large vessels. The charts will be used by the Council to examine changes in area closures or alternative permit schemes for vessels operating inside and outside the Hawaii Exclusive Economic Zone.

Using confidentiality criteria to protect unique fishing locations, 95 percent of total sets were charted in 1991 but only 73 percent in 1992. The lower rate of plotting in 1992 occurred because of the diffusion of the longline fleet that year. As a result, only fishing within latitude 10°-35°N, longitude 180° E-140° W was charted. However, the actual extent of the fishery in 1992 was latitude 0°-45°N, longitude 175°E-140°W.

Figures 2a and 2b indicate the range (nonconfidential) of the fishery in 1991 and 1992 by plotting the number of vessels fishing in 1-degree squares. Plotted values are scalar values from 0 to 5, representing the cumulative unweighted distribution of actual values. The scalar 1 represents the lowest 20 percent of each plotted variable's values, the scalar 2 represents the 20-40 percent range of values, and so forth, with the scalar 5 representing the 20 percent largest values. The range for each scalar is given in the legend at the bottom of the chart. The value 0 in catch-per-unit effort (CPUE) charts represents no catch of a particular species. Figures 2c-d and 3a-d indicate the values for each of the other major variables plotted for 1992.

The charts were prepared by Frederick Dowdell, computer specialist, and Sam Pooley, chief, Fishery Management and Performance Investigation; and Gerard DiNardo, fishery biologist, and William Kwok, computer specialist, Pelagic Resources Investigation. (S. Pooley, [808] 943-1216)

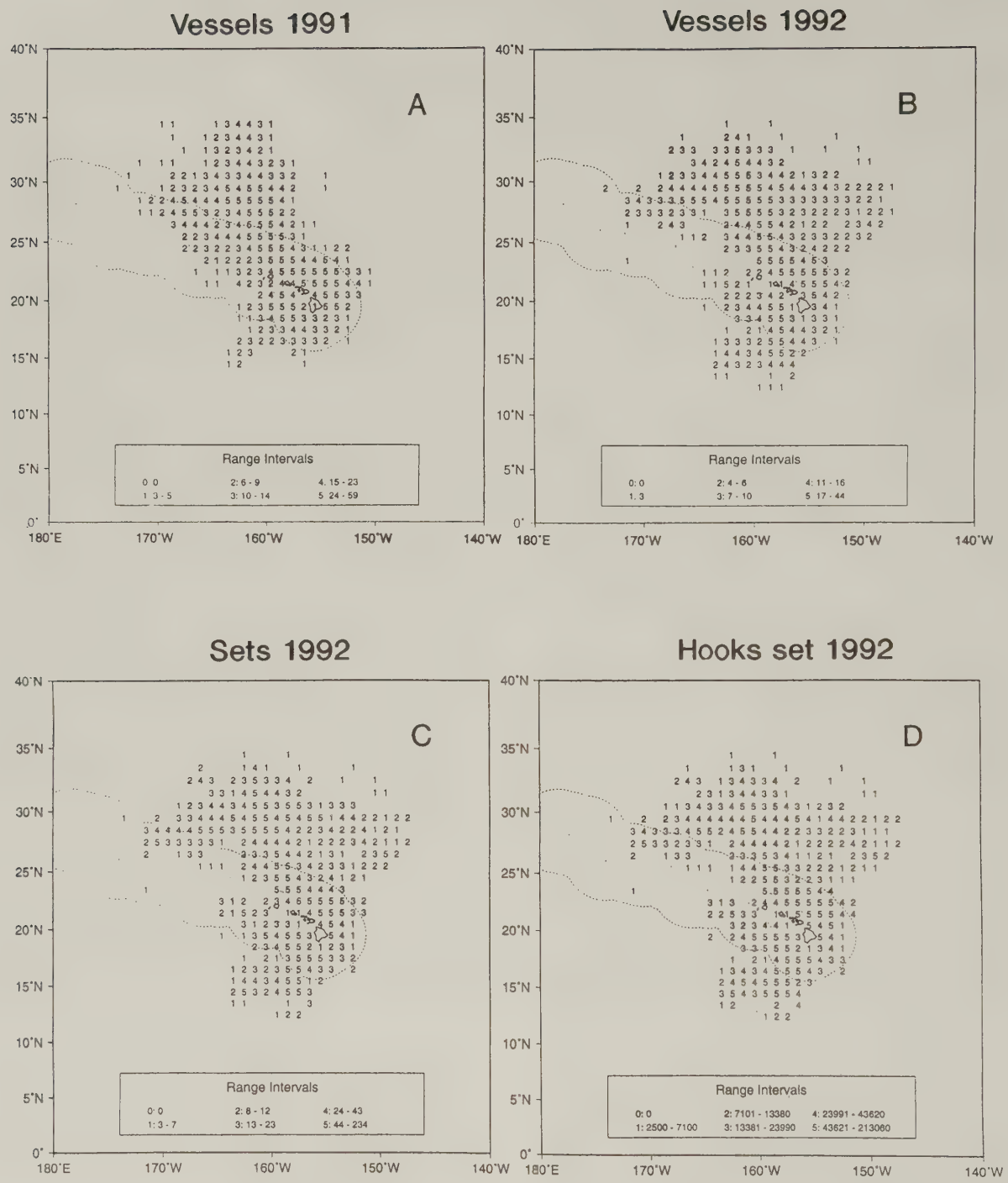

Figure 2. Hawaii longline fishery inside and outside the U.S. Exclusive Economic Zone of the Hawaiian Islands: (a) vessels in 1991, (b) vessels in 1992, (c) sets in 1992, and (d) hooks set in 1992. Range intervals represent number of vessels fishing, number of sets, or number of hooks set in each 1-degree square area.

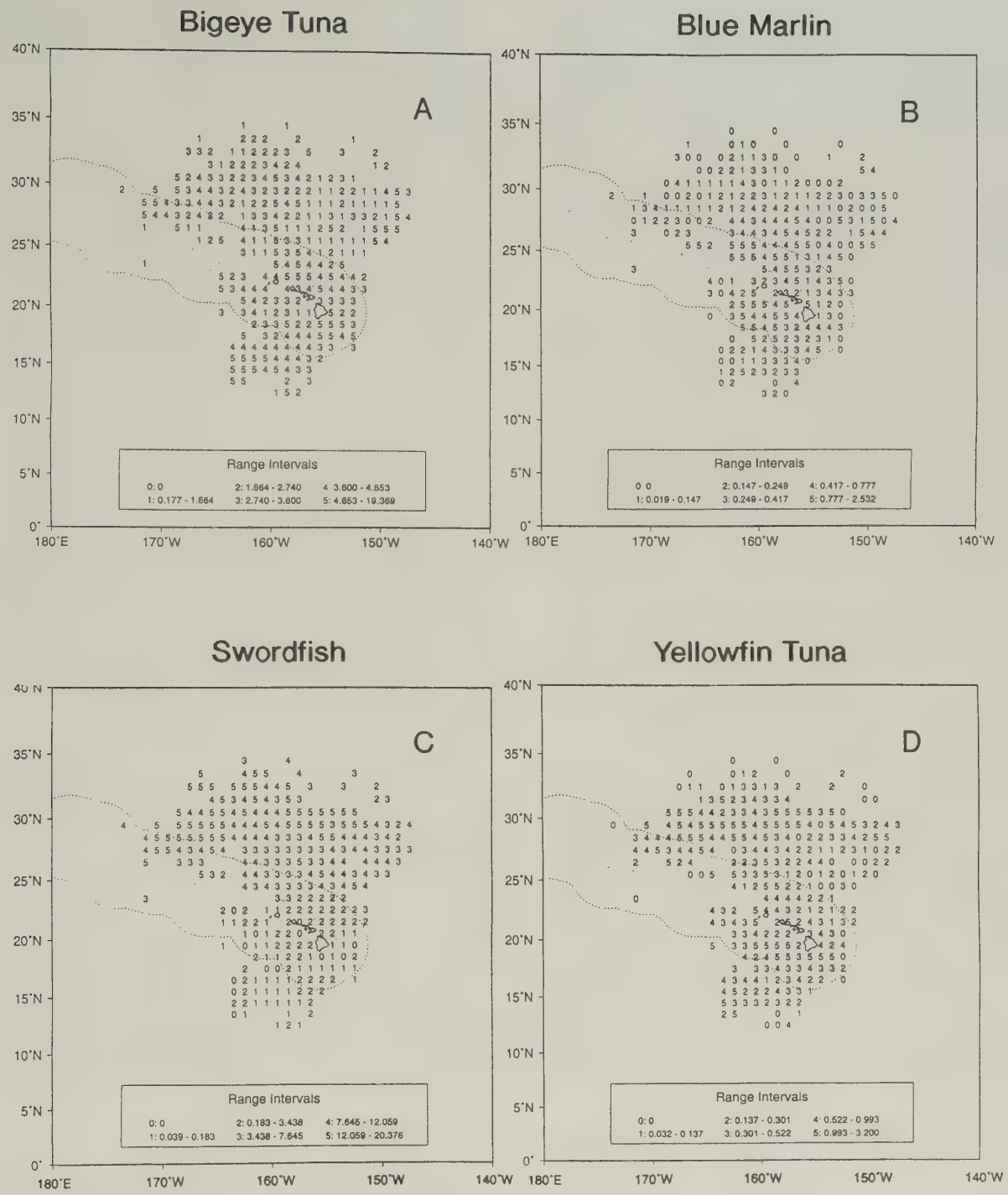

Figure 3. Hawaii longline fishery catch inside and outside the U.S. Exclusive Economic Zone of the Hawaiian Islands in 1992: (a) bigeye tuna, (b) blue marlin, (c) swordfish, and (d) yellowfin tuna. Range intervals represent number of fish caught per 1,000 hooks in each 1-degree square area.

Turtle Mortality Workshop Planned

George Balazs, leader of the Marine Turtle Research Program, and Pooley completed a prospectus for a forthcoming workshop to develop a research plan to investigate the impact of hooking and entangling marine turtles. The overall objective of the workshop is to develop a coordinated research plan, identifying research activities to estimate mortality and physiological impact on marine turtles hooked or entangled in the North Pacific longline fishery.

The workshop was designed in response to the National Marine Fisheries Service Section 7 biological opinion (June 10, 1993) on the domestic longline fishery operating out of Honolulu, which indicates that the incidental take of threatened marine turtles is a concern to the agency. The biological opinion requires an evaluation of the methods and experimental designs that can be used to determine the fate of turtles released alive after being taken by the fishery.

The workshop is scheduled for mid-November 1993. Various experts from across the country are being invited to participate. (S. Pooley, [808] 943-1216)

Alternative Limited Entry Programs Introduced

Ralph Townsend, associate professor of economics at the University of Maine, recently completed his second summer at the Honolulu Laboratory. Townsend worked with Laboratory Industry Economist Sam Pooley on a number of issues concerning limited entry in the Hawaii longline and lobster fisheries. Townsend also presented two seminars at the Honolulu Laboratory: one on the application of chaos theory to dynamic fisheries (the east coast groundfish fishery) and one on alternative management options for the Northwestern Hawaiian Islands (NWHI) lobster fishery.

Several papers have been initiated from this partnership, which was facilitated by the Southwest Fisheries Science Center/Southwest Region socioeconomic research fund. One paper compares a number of hypothetical management alternatives for the NWHI lobster fishery, which is currently managed under a limited entry and seasonal biological quota on spiny, *Panulirus marginatus*, and slipper, *Scyllarides squammosus*, lobsters combined. These alternatives include the now well-known individual transferable quotas (ITQs), queued (annual rotating turns) fractional licensing, indexed transferable input restrictions, and fishery trusts. Each of these alternatives stresses market incentives to management in a fishery that has fairly homogenous and well-informed participants.

ITQs allocate a share of the fishery-wide expected catch to individual vessels, which are then free to catch lobsters up to their individual quota, buy additional quota in order to land more lobsters, or sell quota and reduce their landings. However, ITQs in this fishery might well generate a high grading problem where higher valued spiny lobster are targeted while lower valued slipper lobster are relegated to the second tier, complicating the combined approach to biological assessment.

The "fractional licensing" alternative was developed by Townsend, and Townsend and Pooley explained the alternative to the Hawaii longline fishery. Essentially, it involves determining the optimal-sized fleet (number of vessels) to fish during a year (based on the biological assessment and appropriate economic parameters) and then allocating shares of the fleet total to the participants. Vessels could only fish with a complete share, requiring each vessel owner who chooses to fish to purchase sufficient shares from other owners (who choose not to fish) to make up a full share.

Another way to accomplish the same objective would be to develop a "transferable queuing" system in which participants would have annual rotating "turns" to fish. If the fishery could sustain 5 vessels fishing in any particular year, then vessels 1 to 5 would get to fish, and vessels 6-15 (the actual fleet size) would be out of the fishery for the year. In the next year, if the sustainable fleet were 2 vessels, then vessels 6 and 7 would get to fish, while vessels 1-5 and 8-15 would be out of the fishery. However, vessel owners out of the queue could lease the right to fish during a particular year. (In the last example, they would lease from vessels 6 and 7).

Another alternative would be an input restriction based on "indexed transferable inputs" of the number of traps a vessel could carry. When the biological assessment indicated that the appropriate number of traps to be fished during the year was less than the optimal number for all vessels in the fleet, some vessels could sell or lease their trap allocation to other vessels, or they could fish "suboptimally" with a reduced number of traps if their assessment differed from the fishery managers.

Finally, the "fishery trust" involves the idea of privatizing fishery management. Participants in the fishery would be given the responsibility of making regulations they felt necessary to manage their collective participation. This responsibility would probably be exercised through some form of corporate directorship of the vessel owners (and potentially captains, crews, and buyers) with formal authority remaining with the existing fishery management councils. Also envisioned in this alternative is the privatization of the annual stock assessment research (and presumably economic assessment) and privatized enforcement through contracted auditors. The extent to which the trust would interact with existing fishery agencies, particularly NMFS, is yet to be determined.

Each of these alternatives attempts to overcome the economic inefficiencies which are substantial in the current biological regulatory schemes. However, each has its own limitations, and collectively, they suggest a basic question concerning the equity of the initial allocation of rights to the participants. While "grandfathering" has been common in limited entry and ITQ programs, there is increasing concern that the privatization of fisheries must have a broader social benefit. In situations where cattle and sheep graze on Federal lands, the size of the grazing fee is a matter of substantial public debate. The Magnuson Fishery Conservation and Management Act has not been interpreted by the NOAA General Counsel to allow for such fees, yet fees themselves are also a major alternative methodology for natural resource regulation. (S. Pooley, [808] 943-1216)

PELAGIC FISHERIES RESOURCES DIVISION

La Jolla, California

MULTISPECIES DATA COLLECTION AND EVALUATION PROGRAM

Dolphin Mortality in U.S. Tuna Fishery Continues to Decline

The estimated number of dolphins killed in the U.S. eastern tropical Pacific tuna purse seine fishery in 1992 was 438, down 56 percent from the estimated 1991 kill of 1,004 animals, according to data collected by on-board observers from the National Marine Fisheries Service. The 1992 dolphin kill was well below the annual quota of 20,500 and was the lowest on record for the U.S. fleet. This quota was reduced to 800 dolphins for the period of January 1, 1993, to February 28, 1994, by passage of the International Dolphin Conservation Act of 1992 by the U.S. Congress.

The major reasons for the marked decrease in dolphin kill in 1992 were the continued reduction in the size of the U.S. fleet and an increase in the fishing effort on non-dolphin-associated tuna by the remaining U.S. vessels; both are largely the result of the U.S. tuna canners' decision in April 1990 to purchase only "dolphin-safe" tuna.

In 1991 there were 13 U.S. purse seiners active in the eastern tropical Pacific, of which 9 made sets on dolphin-associated schools. In 1992 the active fleet declined to seven vessels, of which only five made sets on dolphin-associated schools. In both years, 1991 and 1992, the observer coverage rate was virtually 100 percent. Forty fishing trips and 430 dolphin-associated sets were observed in 1991. In 1992, 40 trips and 650 dolphin-associated sets were observed. The dolphin kill-per-set rate in 1992 was 0.7, down 70 percent from the 1991 rate of 2.3 dolphins per set. This was the lowest annual rate ever achieved by the U.S. fleet (Fig. 1).

Based on preliminary data from observed trips completed during the first 8 months of 1993, the dolphin kill and kill-per-set rates remain at historical lows: 75 dolphins killed in 99 sets for a kill-per-set rate of 0.8. Of the eight U.S. purse seiners that are active in the eastern tropical Pacific and permit-

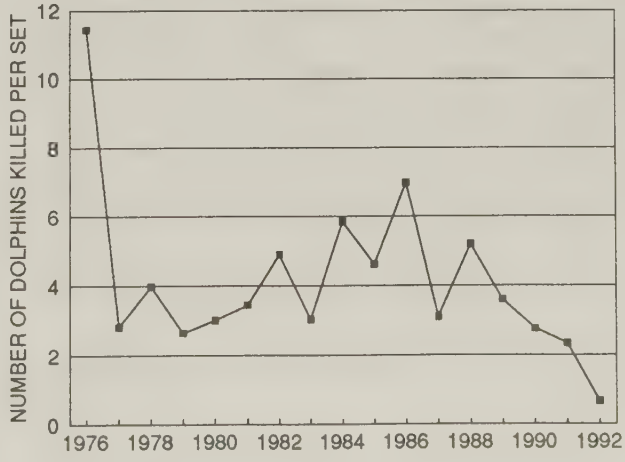

Figure 1. Average number of dolphins killed per set on dolphins for observed U.S. trips, 1976 to 1992.

ted to set on dolphins, only three actually made dolphin-associated sets during this period. (A. Jackson, [619] 546-7048)

Albacore Fishery Data Summarized

Gary Rensink, fisheries biological technician, has completed two administrative reports, LJ-93-10, "Summary of the 1991-92 South Pacific albacore fishery data," and, with coauthor Forrest Miller of the Inter-American Tropical Tuna Commission, LJ-93-12, "Summary of the 1992 North Pacific albacore fisheries data." Approximately 400 copies of the reports have been distributed to members of the Western Fishboat Owners Association, who voluntarily submit logbook data used for the reports.

South Pacific Fishery. The 1991-92 U.S. South Pacific albacore fishery started December 1991 and went through April 1992. The fishery was centered mainly south of French Polynesia. The number of U.S. jig vessels participating in the fishery was 35, a decrease from the 58 that participated during the 1990-91 fishing season. The total landing of albacore was 3,016 metric tons (t), a decrease from the 5,540 t that were landed in the 1990-91 fishing season. Average catch rate was also lower in 1991-92 (130 fish per day) than in 1990-91 (193 fish per day). The average size of albacore caught was 6.7 kilogram.

North Pacific Fishery. The 1992 U.S. North Pacific albacore fishery began in mid-May and continued into early November. As in past fishing seasons, the fishery started in the mid-Pacific off Midway Island early in the season and gradually moved eastward to the Oregon and Washington coastlines as the season progressed. Ocean frontal boundaries along the west coast were prevalent during the season, contributing to moderately good fishing between Vancouver Island and Cape Mendocino. Landings increased by 148 percent from landings in 1991 to 4,572 t, the highest recorded since 1988. Average catch rate was 54 fish per day, an increase from 1991 (36 fish/day). Fish averaged 5.4 kilograms in 1992. (G. Rensink, [619] 546-7079)

STOCK ASSESSMENT AND FISHERY IMPACT ANALYSIS PROGRAM

International Pacific Swordfish Symposium Planned

An International Pacific Swordfish Symposium, hosted by Centro de Investigacion Cientifica y Educacion Superior de Ensenada (CICESE) with assistance from the Southwest Fisheries Science Center, is being planned for December 1994 at CICESE in Ensenada, Mexico. The symposium will focus on recent developments in Pacific swordfish fisheries, markets, and biological research. A first announcement and call for papers has been issued by the symposium Chairman, Dr. Oscar Sosa of CICESE. Papers will be peer reviewed and published following presentation at the symposium. This symposium is the first meeting in the Pacific dedicated exclusively to swordfish. (N. Bartoo, [619] 546-7073)

PELAGIC ECOSYSTEM MODEL DEVELOPMENT PROGRAM

Tuna Movement Model Developed

Movement is a natural phenomenon of great importance in the lives of many fish species, but this phenomenon has been largely neglected in stock assessment models. Tuna are no exception. Much of Pelagic Ecosystem Model Development Program Leader Pierre Kleiber's research is devoted to making tuna movement models for the twofold purpose of measuring parameters of movement by fitting the models to data and incorporating movement information into tuna stock assessments.

One of the problems Kleiber has encountered in developing movement models of tuna is the high rate of movement in relation to the temporal and spatial scales that he is dealing with. To implement such models on a computer, it is necessary to divide time and space into discrete increments. In a recently developed model having two spatial dimensions, the time was divided into 1-month increments, with the spatial cells measuring approximately 50 km on each side. The population turnover in such cells can typically be several hundred percent per time step. To generate a solution, one needs to predict a population in one time increment Δt based on the population at the current time t. That is,

$$P^{t+\Delta t} = P^t + f(P^\tau)$$

where the model is embodied in function f of the population at some time τ during the interval. With explicit forward time stepping, τ is assumed to be the start of the time interval, that is, t. With this scheme, the high turnover is bound to produce unstable solutions, that is, the predicted population will undergo wild swings at each time step and the model will probably crash.

There are two ways to reduce the turnover per time step, each with its own drawback. One way is

to divide the time steps into small substeps, but that multiplies the computational load in proportion to the number of substeps. Another way is to use larger spatial cells, but that reduces the spatial resolution. Another tactic, suggested by W. H. Press, B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling in their book *Numerical Recipes in C* (1992), is to use implicit instead of explicit forward time stepping. In this case, τ in the above equation is set to the end of the time interval, that is, $\tau=t+\Delta t$, which means that the equation must be solved for the unknown $P^{t+\Delta t}$. This has the potential of achieving stability even though turnover is high. For a diffusion situation having one spatial dimension, an implicit time step involves solving a tri-diagonal equation system, in effect inverting a tri-diagonal matrix. Computationally, this is very quick and easy to do. The order of the matrix is the number of cells.

For two spatial dimensions, the problem is more difficult. The order of the matrix to invert is still the number of cells, but there tends to be many times more cells. Kleiber's recent model had an 18 x 22 grid, that is, 396 cells. Furthermore, the equation system is no longer tri-diagonal. In these circumstances, Press et al. suggest an alternating direction implicit (ADI) scheme which first takes a half time step formulated with implicit steps along the rows of cells in one spatial dimension and explicit steps in the other dimension. Then the formulation is, in effect, rotated 90 degrees and repeated for the second half-step. For Kleiber's model, this involved 18 tri-diagonal solutions for the first half-step and 22 such solutions for the second half-step. With pure diffusion, Press et al. state that ADI is unconditionally stable. However, with Kleiber's model, which had added complications of spatially heterogeneous movement parameters and mortality, he found that unconditional stability was no longer true, and he had to divide the time step into four or more substeps depending on the magnitude of the movement parameter.

Just recently, Kleiber tried a fully implicit scheme for his model on the theory that it might be unconditionally stable and that it would not be too slow to compute. He found that the equation system is very sparse and structured. The matrix is penta-diagonal, with the two outer diagonals being displaced slightly and the inner diagonals having some zero elements (Fig. 2).

In this preliminary work, Kleiber implemented a "quick and dirty" solution scheme for an 18 x 22 grid using Splus, a data analysis package that allows quick implementation of a computation scheme,

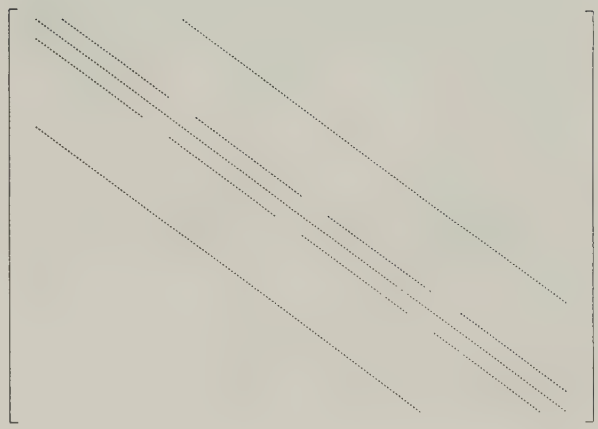

Figure 2. Structure of matrix for solution of a fully implicit time step for a movement model in two spatial dimensions.

but not necessarily high efficiency in the actual computations. The method involves solving an equation system of order 396 for each time step. Because the model parameters do not change with time, the matrix elements also do not change, and it is convenient to precalculate a Q-R decomposition of the matrix from which solutions can be efficiently generated.

For this size problem, the precalculation took less than one minute on Kleiber's computer, and thereafter, each time step took about six seconds. This is about twice as long per time step as it takes with the ADI scheme, but the ADI scheme is implemented in C++, a computer language which is much more computationally efficient than Splus. Because this preliminary scheme takes no advantage of the structure of the matrix and because it is not coded in C++, Kleiber believes that a fully implicit scheme may be computed at least as efficiently as the ADI scheme. Furthermore, the fully implicit scheme is stable with no substeps and with order-of-magnitude and larger movement parameters than Kleiber has heretofore used in the model. He believes that perhaps the scheme is unconditionally stable, but it hasn't been checked mathematically yet.

Stability is a very useful property when wanting to run the model with a variety of parameter values and not having to worry about adjusting the number of substeps. This is particularly important when the model is being used for parameter estimation and the parameters are therefore being adjusted automatically by some sort of iterative optimization algorithm. The fully implicit time

stepping scheme for movement models is promising in this context, and Kleiber will be looking for a solution method that takes advantage of the structure of the penta-diagonal matrix. (P. Kleiber, [619] 546-7076)

TIBURON LABORATORY

Tiburon, California

GROUNDFISH ANALYSIS INVESTIGATION

Yellowtail and Widow Rockfish Otolith Growth Reduced During 1983 El Niño

For many years, Fishery Biologist David Woodbury has been ageing yellowtail rockfish, *Sebastes flavidus*, otoliths collected from Cordell Bank, located 20 nautical miles off Pt. Reyes, California, and has observed a reduction in otolith growth corresponding to the 1983 El Niño. To quantify these observations, he measured the area of the first six or seven annuli (yearly rings) in 150 female yellowtail rockfish otoliths using the following method. With the aid of a camera lucida (a device that projects a microscope image onto a flat surface) mounted atop a dissecting microscope, the annuli were traced from the surface of whole otoliths. A digitizing pad was then used to determine the area of the annuli from the tracings. Results revealed a significant reduction in otolith growth during 1983. These findings were presented at the 1992 California Cooperative Oceanic Fisheries Investigations Conference in Monterey, California.

The study was then expanded to include both sexes of two rockfish species, yellowtail and widow (*S. entomelas*) rockfish, collected from the ports of San Francisco and Eureka. Because the method used to measure annual growth was very time consuming, Woodbury was only able to process about 1-2 otoliths per hour. Fortunately, the Groundfish Analysis Task recently acquired an image enhancement system that utilizes a MacIntosh computer interfaced with a high resolution camera and dissecting microscope. Using this system, he was able to capture an image, enhance it, and measure the annuli in 15 percent of the time required by the former method. To compare the two methods, he remeasured the first six annuli from five otoliths previously measured by the first method. Differences in annual growth increments between the two methods ranged from 0.2-11.4 percent, with a mean of 2.9 percent. With this new system, Woodbury was able to process the additional otoliths both rapidly and accurately. The results in each species-sex-port combination revealed similar patterns of growth and will be presented in a future manuscript. Figure 1 shows the results from female widow rockfish collected from the two ports. (D. Woodbury, [415] 435-3149)

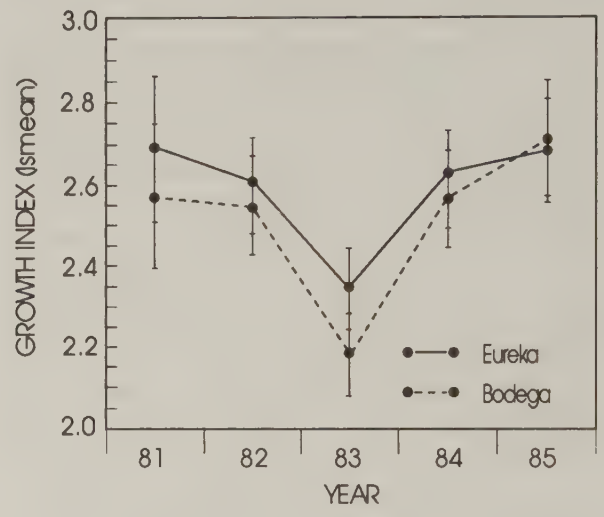

Figure 1. Annual otolith growth (1981-85) of female widow rockfish collected from Eureka and San Francisco ports. Growth Index based on least squares mean approach.

GROUNDFISH COMMUNITIES INVESTIGATION

1993 Salmon Predation on Juvenile Rockfishes Shows Unusual Pattern

The occurrence of rockfish recruits in the diet of king salmon has been monitored by Fishery Biologists Pete Adams and Kelly Silberberg since 1980. Until this year, the predation has been concentrated during a single period, usually mid-May to mid-June, and the major species taken has been the shortbelly rockfish, *Sebastes jordani*. This past recruitment season has been unusual because there were two distinct periods of predation and the major species taken during the first of these was the stripetail rockfish, *Sebastes saxicola*.

The first occurrence of rockfish recruits in the salmon diet was on April 26, which is considerably earlier than usual, and the period of predation continued until May 14. Recruits taken were relatively

small, about 35 millimeters in standard length (mm SL), which may have been due to their appearance early in the recruitment season, and they occurred in moderate numbers (2.1 per salmon). Stripetails represented 64 percent of the individuals recovered from the stomachs, thus marking the first time that this species has dominated the diet. Furthermore, while shortbellies were prominent, at 32 percent of the individuals eaten, this is the first time that this species has not represented more than 50 percent.

The second period of predation lasted just five days, July 8-12, but the juveniles taken were larger (about 55 mm SL) and feeding was far more intensive (63 per salmon). This time, all the juveniles recovered from the salmon stomachs were shortbellies. (P. Adams, [415] 435-3149)

GROUNDFISH PHYSIOLOGICAL ECOLOGY INVESTIGATION

Ovary Lipid Concentration Relates to Fecundity in Yellowtail Rockfish

An objective of the research conducted by the Groundfish Physiological Ecology Investigation (GPEI) has been to determine which physiological processes in maternal yellowtail rockfish, *Sebastes flavidus*, relate to reproductive success. Measures of reproductive success include (1) quantitative estimates of oocytes and embryos and (2) qualitative determinations of their health, or condition, and nutritional energy status.

GPEI's research over the past eight annual reproductive cycles has shown lipids to be the nutrient class most responsive to annual and interannual variability of environmental conditions and their subsequent maternal physiological manifestations. GPEI scientists have also determined that yellowtail rockfish are mainly lecithotrophic, that is to say, maximal accumulation and quantities of nutrient components for oocytes and embryos occur primarily prior to fertilization.

Since lipids are the major energy storage form in yellowtail rockfish, as in most marine teleosts, the fishery biologists hypothesized that there is a relationship between lipid content in ovaries and reproductive success. To test this hypothesis, they regressed annual means of relative fecundity (number of oocytes or embryos per gram of somatic weight) on the concentration of total lipids in ovaries just prior to fertilization (ovary maturation stages [OMS] 3 and 4, or late yolk accumulation and migratory nucleus stages, respectively).

The results indicated a highly significant ($P<0.001$) relation between fecundity and ovary lipid levels for the Cordell Bank yellowtail rockfish population during the reproductive years 1988 through 1992 (Fig. 2). This association suggests that environmental conditions that produce good feeding and consequent accumulation of lipids also result in the promotion and maintenance of the greatest number of oocytes on an age-specific basis. It is known that gonadotropin, a gonad stimulating hormone, and ovarian steroidal hormones control the maturation of oogonia, primordial germ cells that give rise to oocytes. Thus, it is reasonable to presume that environmental factors favorable to the accumulation of lipids are also beneficial to reproductive neurohormonal processes. (B. MacFarlane, [415] 435-3149)

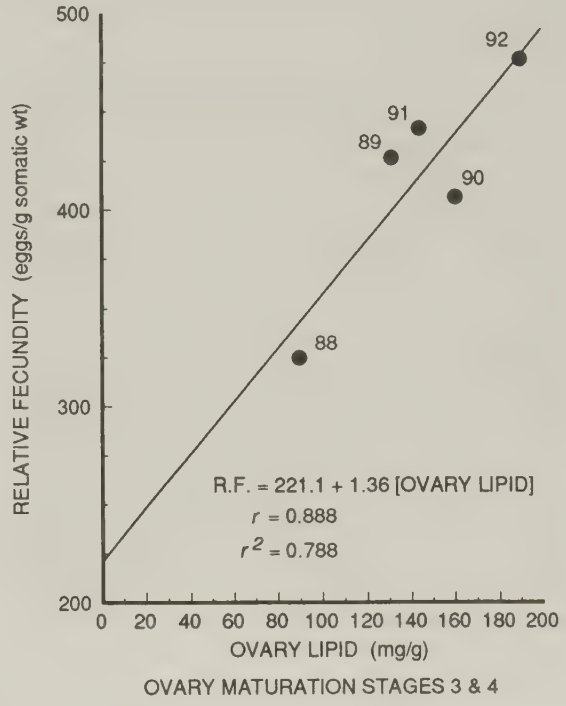

Figure 2. Relationship between the mean annual relative fecundity of yellowtail rockfish from Cordell Bank and the concentration of lipids in ovaries just before fertilization during the reproductive years 1988 through 1992.

Widow Rockfish Feeding Studied

Tiburon Fishery Biologist Don Pearson and David Douglas and Bill Barss, of the Oregon Department of Fish and Wildlife, recently studied widow rockfish *Sebastes entomelas*, from the Cobb

Seamont and coauthored "Biological observations from the Cobb Seamont rockfish fishery," which is to be published in *Fishery Bulletin*. Their studies showed that widow rockfish from the Cobb Seamount, located approximately 200 miles from the Oregon coast, had unique life history characteristics that distinguished them from coastal populations. The majority of Cobb widow rockfish had a narrow age range and were less than 9 years of age. They also appeared to reach sexual maturity at a younger age than other populations. The otoliths of these fish, which are used for determining ages, had an unusually high incidence of crystallization, suggesting that there may be diet-related problems in fish associated with this remote seamount. In order to determine if diet is a determinate factor, NOAA Junior Fellow Penny Ruvelas and Fishery Biologist Pearson are conducting a stomach analysis study comparing widow rockfish from Cobb Seamount with those from the central Oregon coast.

Landings from the commercial fishery have been sampled and preliminary findings show continued distinctions between the populations. Cobb Seamount fish were uniform in size and small, in contrast to the more diverse and larger coastal fish. Whole body examinations of adult fish showed that Seamount widow rockfish had more abundant mesenteric fat stores and fewer parasites than their coastal counterparts. Coastal fish were almost devoid of fat. Stomach content analyses continue to be identified, quantified, and analyzed. Initial results show the Cobb widow rockfish fed primarily on salps, *Salpa* and *Thetys*, during the late winter and early spring, and on euphausiids and hyperiid amphipods, *Hyperoche* and *Vibilia*, during the summer. There does not appear to be any major difference between the Cobb widow rockfish diet and, based on previous studies of coastal widow rockfish, the coastal rockfish diet. (P. Ruvelas, [415] 435-3149)

INFORMATION TECHNOLOGY SERVICES

Oracle Server Implemented for IT-95 Training Resource

After 8 years of administrative procedures, procurement of Information Technology (IT-95) systems has been awarded and begun. The first stages of the transition to new hardware and software platforms involve data directory/inventory, software conversion, implementation of data standards, and training. IT-95 Unix-compliant workstations and multi-user Oracle licenses have been specified for head-start training of users in the Southwest Fisheries Science Center's La Jolla, Honolulu, and Tiburon Laboratories.

In preparation for data base redesigns and application software conversion for the IT-95 system platforms, a Sun Sparc 10 workstation was installed as an Oracle server at the La Jolla Laboratory. It is a training resource for the staff to learn about relational data bases and the Oracle system.

Oracle, self-described as a provider of cooperative server technology for transparent data sharing, was chosen to satisfy the IT-95 objective of a distributed processing network for complex scientific and general administrative computing. Data Base Management Systems (DBMS) manage data for multiple users concurrently accessing the same data, while delivering high performance. A DBMS must also be secure from unauthorized access and provide for failure recovery. The Oracle Server effectively provides these major data base features.

Oracle offers Computer-Aided Systems Engineering (CASE) tools, a combination of software tools and structured system development methodologies. CASE enables analysts and designers to work effectively and efficiently in a structured way. As the methodology is now largely computer-based, some of the advantages of modern computing can be fully exploited by the windowing system. In theory, each window displayed could be working on different computers, and these need not be under the same roof. True simultaneous development is possible, even internationally.

Development of a system using CASE products from Oracle has the advantage of a shared data base. This enables rapid development cycles with improved accuracy. More time is available for careful analyses of problems and greater levels of discussion between developers and users.

In addition to the Oracle Relational Data Base Management System and its associated CASE tools, other resources available on the Sun are electronic mail through the Internet, C, SparcWorks development and environment, OpenWindows, X Windows server support, USENET, on-line help facilities, and backup services.

Also, in October, the Sun will become the print server for the high-speed line printer (Printronix) in office B-110. In addition to printing Vax jobs, it will also provide printing capabilities to any of the Center's Unix machines through the UCSD Local Area Network (LAN).

Assistance on Sun Unix accounts and Oracle data base design and operations can be obtained from Susan Jacobson. Assistance on the availability of Unix and Oracle self-training tools can be obtained from Thanh Vu. Manuals can be used in office B-113. (S. Jacobson, [619] 546-7060)

AIMS Modules to be Implemented at the SWFSC Remote Sites

Administrative Information Management System (AIMS) is a long-range project being developed to meet the expressed needs of SWFSC/SWR users in managing their resources effectively and efficiently. The modular structure of AIMS allows for phased implementation of the information categories according to a priority schedule set by SWFSC users. Several applications have been implemented and are currently working at the La Jolla site. According to the plan, AIMS would support the staff at all SWFSC locations. With funding now available, the AIMS applications for remote laboratories will be implemented during FY 94.

Jan Pappas, computer specialist at the Honolulu Laboratory, expressed interest in having the Envelope Manager, Imprest Fund, Personal Property systems and the Small Purchase System (SPS) set up at their site. Envelope Manager, a PC DOS-based mailing label management system, has been purchased and is ready for installation on their LAN. It will be available to anyone with access to the LAN. The other two applications ready for implementation are the Imprest Fund Voucher System and Personal Property System. The Imprest Fund Voucher System is an existing system that was developed by the Budget Office of Pacific Marine Center to improve the imprest fund administration and to ensure rapid and accurate monitoring of the money involved. Personal Property is a system developed by Information Technology Services. This system will provide the staff with fast and flexible centralized control of accountable inventory. Implementation of SPS will be delayed until the release of the new version in November 1993. This system was developed by the Department of Commerce's Office of Personnel Management and Office of Information System to control and standardize ordering information such as requisitions, procurement orders, and blanket purchase agreements. Because SPS is a FOCUS-based system, FOCUS software must be installed on a PC before it can operate SPS. In addition, since the purchase order form CD-404 is an eight-part form, the SPS application must be linked to an impact printer.

In consultation with Pappas, Vu identified the required equipment and software for implementing the AIMS modules at the Honolulu Laboratory. To support their hardware and software requirements, ITS purchased a 486 PC, Envelope Manager, and FOCUS. Their printer requirements will be satisfied by their existing NEC 8810 Spinwriter printer, which is capable of printing through the eight-part form for the SPS. The equipment and software will be shipped to Honolulu by the first quarter of FY 94. Vu will provide remote support to assist Pappas in implementing the AIMS modules.

Issei Yokota, Administrative Officer, Tiburon Laboratory, requested implementation of three AIMS modules: the Imprest Fund, Personal Property, and SPS. To support their hardware and software requirements, ITS purchased a multiple-part Okidata 3410 printer and FOCUS. The Tiburon Laboratory staff currently uses the Envelope Manager application and has an existing PC for implementing the AIMS modules. Their requested AIMS modules will be installed at the Tiburon site during the first quarter of FY 94.

For the Pacific Fisheries Environmental Group, at Monterey, the plan is to have LAN Manager Remote Server software installed to allow remote access to the Financial Report System that resides on the La Jolla LAN. Configuration of the remote software and the written procedures and documentation for the remote set up process will be developed during the first quarter of FY 94.(T. Vu, [619] 546-7061)

PUBLICATIONS

Published

Adams, P. B., S. Ralston, and T. E. Laidig. 1993. Occurrence of an exceptional catch of pelagic juvenile lingcod (*Ophiodon elongatus*) off Point Reyes, California. Fish. Oceanogr. 2(2):97-100.

An exceptionally large catch of pelagic juvenile lingcod, *Ophiodon elongatus*, was made just offshore of Point Reyes, California, in 1990. Results of 678 midwater trawls from annual surveys from 1983 to 1990 show that pelagic juvenile lingcod have a strong near-

shore distribution and were most abundant in the Gulf of the Farallones, with a mean abundance of 5.0 per trawl. Otoliths from fish taken in the large catch were used to estimate parameters of a log-transformed Gompertz growth model, which was then used to calculate hatch dates. Hatching peaked around March 24 and ranged from March 10 to April 19, implying a January-February spawning season for lingcod off central California. The large catch was associated with an anticyclonic eddy which would lead to water being trapped near the coast; convergence of fish associated with the eddy may have been due to either physical or biological effects.

Balazs, G. H., R. Fujioka, and C. Fujioka. 1993. Marine turtle faeces on Hawaiian beaches. Mar. Pollut. Bull 26:392-394.

Faeces of the green turtle, *Chelonia mydas*, washed ashore in large numbers at a beach park in Hawaii over a 40-day period in 1989. The formed pellets were originally misidentified as being from pigs or humans, and therefore were perceived as a pollutant of potential health hazard to humans. However, bacteriological analysis of the nearshore waters indicated low and legally acceptable levels of faecal coliforms and enterococci. Similar diminished levels were also found in direct cultures of the fresh pellets. Green turtle faeces have been known to drift ashore in Hawaii, but never in the quantities recorded during this short-term event. The reason for the occurrence could not be determined, but several possible explanations are given.

Bence, J. R., A. Gordoa, and J. E. Hightower. 1993. The influence of age-selective surveys on the reliability of stock synthesis assessments. Can. J. Fish. Aquat. Sci. 50(4):827-840.

Monte Carlo simulations were used to examine the reliability of assessments following a method of separable catch-at-age analysis (Methot's stock synthesis approach). The simulations were based on the widow rockfish, *Sebastes entomelas*, fishery off the west coast of the continental United States. The study was designed to examine how the performance of the method depended upon the age-specific selectivity pattern of a survey of relative abundance. When survey selectivity increased asymptotically with age, stock synthesis estimates of final year biomass (and most other parameters) tended to be closest to the correct value. When the survey concentrated on young fish, the estimates were least reliable. When the survey selectivity was "dome-shaped," concentrating on intermediate-aged fish, estimates were somewhat less precise (and less accurate) than for the asymptotic pattern but much more precise than for the survey concentrating on young fish. Predictable estimates of recruitment and biomass were better at a higher fishing mortality rate and when the magnitude of survey error was lower. Generally, mean errors in estimated biomass and recruitment were positive, while median errors were close to zero. This pattern is due to transformation bias associated with a lognormal error structure.

Bigelow, K. A., and K. C. Landgraf. 1993. Hatch dates and growth of *Ommastrephes bartramii* paralarvae from Hawaiian waters as determined from statolith analysis. *In* Okutani, T., R. K. O'Dor, and T. Kubodera (eds.), Recent advances in cephalopod fisheries biology, p. 15-24. Tokai University Press, Tokyo.

Planktonic young (paralarvae) of *Ommastrephes bartramii* have recently been found in early spring (March-May) along the Hawaiian Archipelago. Statoliths of paralarvae ($N = 57$) sampled in February 1991 were used to estimate ages, hatch dates, and growth rates. Growth increments within statoliths were enumerated using light and scanning electron microscopy. Under the assumption that increments were formed daily, paralarvae were estimated to grow exponentially for at least 35 days post-hatching. Based on the growth model, paralarvae 15, 25, and 35 days old had estimated mantle lengths of 1.6, 4.3, and 12.1 mm, respectively. The paralarvae were estimated to have hatched between January 1 and 25, 1991, based on back calculation of statolith increments from the time of capture.

Davenport, J., G. H. Balazs, J. V. Faithfull, and D. A. Williamson. 1993. A struvite faecolith in the leatherback turtle *Dermochelys coriacea* vandelli: A means of packaging garbage? J. Herpetol. 3:81-83.

A large stone-like object was collected from the rectum of a leatherback turtle beached at Midway Atoll, Hawaiian Islands. It consisted of biomineralized faecal material, the mineral being struvite ($NH_4MgPO_4 \bullet 6H_2O$). Much material of anthropogenic origin (plastics in sheet and linear form, plus other packaging materials and monofilament nylon) was incorporated into the faecolith structure. It is hypothesized that the formation of struvite stems from the interaction of the leatherback's osmotic physiology with the metabolism of faecal bacteria. While the formation of the faecolith may be pathological, it could alternatively be an adaptive response to package garbage (whether natural or man-made).

DeMartini, E. E., D. M. Ellis, and V. A. Honda. 1993. Comparisons of spiny lobster *Panulirus marginatus* fecundity, egg size, and spawning frequency before and after exploitation. Fish. Bull., U.S. 91(1):1-7.

Size-specific fecundities of spiny lobster, *Panulirus marginatus*, were compared for two time-periods: pre- and early exploitation or "before" (1978-81), and post-exploitation or "after" (1991). Fecundity was further evaluated within each time-period at two collection sites that represented the major lobster fishing grounds (Maro Reef and Necker Island) in the Northwestern Hawaiian Islands. Complementary data on egg size and spawning-frequency index were compared between study sites and time-periods.

Study sites and time-periods had no observable effects on egg size or spawning frequency, and there was no temporal effect on fecundity at Maro Reef. Fecundities at the two sites differed, however, "after" size-specific fecundity was an estimated 16±9 percent greater than "before" fecundity at Necker Island. Observations suggest that the recent increase in fecundity at Necker Island may reflect a compensatory (density-dependent) response to greater exploitation at this site. Results are discussed in terms of evidence for density-dependent responses in other exploited spiny lobster stocks.

Jackson, A. R. 1993. Summary of 1989 U.S. tuna-dolphin observer data. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-183, 31 p.

Jacobson, L. D., and C. J. Thomson. 1993. Opportunity costs and the decision to fish for northern anchovy. N. Amer. J. Fish. Manage. 13:27-34.

Since 1982, declines in the U.S. reduction fishery for northern anchovy, *Engraulis mordax*, were due to ex-vessel prices too low to meet opportunity costs of traditional crew members in the southern California wetfish fleet, rather than to inability to meet variable (short-run) costs for items such as fuel. The decline of the fishery appeared to be driven largely by opportunity costs, which, in turn, depended on the ethnic background of crew members. Our analysis indicated that opportunity costs and sociological factors, which are often ignored by fishery managers who traditionally focus on biological analyses, can affect a fishery and its performance. Estimates of opportunity and variable costs from our study should be useful in the development of management plans for the wetfish fishery.

MacCall, A. D. 1993. Overview paper: Advice for stock rebuilding. *In* Rosenberg, Andrew (ed.), Defining overfishing—defining stock rebuilding. Report of the Second Annual National Stock Assessment Workshop, p. 47-59. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-F/SPO-8.

Norton, J. G., and D. R. Mclain. 1993. Year-to-year changes of vertical temperature distribution in the California Current region: 1954 to 1986. Proceedings of the Ninth Annual Pacific Climate Workshop, April 21-24, 1992. Redmond, K. T., and V. L. Tharp (eds.), California Department of Water Resources, Interagency Ecological Studies Program Report CL/PACLIM92-34.

Remote forcing from the Equatorial Pacific and local forcing from the North Pacific lead to interannual ocean temperature change along the west coast of the United States. In fall-winter seasons, coherent temperature changes extending from the surface to 300-m depths indicate remote forcing. Correlations between time series of ocean temperature change and series of equatorial sea level pressure (SLP) at 12.4° S x 130.9° E were as great below 100 m as at the surface. From 1954 to 1986, coherent warming events occurred only during moderate to strong El Niño years. Warming events more closely related to local North Pacific SLP at 45° N x 165° W have correlations which were greatest at the ocean surface.

Okihiro, M. S., J. A. Whipple, J. M. Groff, and D. E. Hinton. 1993. Chromatophoromas and chromatophore hyperplasia in Pacific rockfish (*Sebastes* spp.). Cancer Res. 53:1761-1769.

Pacific rockfish from Cordell Bank, off central California (United States), were collected and histologically examined from 1985 to 1990. Hyperplastic and neoplastic cutaneous lesions, involving dermal chromatophores, were observed in five species; yellowtail rockfish, *Sebastes flavidus*, bocaccio, *S. paucispinis*, olive rockfish, *S. serranoides*, widow rockfish, *S. entomelas*, and chilipepper rockfish, *S. goodei*. Yearly prevalences were highest in *S. paucispinis* (29-38 percent). Prevalence was initially low in *S. flavidus*, but increased more than 3-fold from 1985 (7.5 percent) to 1990 (25 percent). The majority of lesions were black, but white, yellow, orange, red, and mixed-color variants were also seen. Lesions were found in skin, fins, lips, gingiva, tongue, urogenital papilla, conjunctiva, and cornea of the eye. Flat lesions were consistent with melanophore (black), xanthophore (yellow or orange), and erythrophore (red) hyperplasia. Neoplastic lesions included melanophoromas, amelanotic melanophoromas, xanthophoromas, erythrophoromas, and mixed chromatophoromas. Although etiology has not been determined, interest is currently focused on potential exposure to chemical and radioactive carcinogens from Farallon Island Radioactive Waste Dump, 30 km to the south.

Pérez, N., I. Figueiredo, and B. J. Macewicz. 1992. The spawning frequency of sardine, *Sardina pilchardus* (Walb.), off the Atlantic Iberian coast. Bol. Inst. Esp. Oceanogr. 8(1):175-189.

Oocyte development for *Sardina pilchardus* was established, and a histological classification of postovulatory follicle aging was developed from the examination of laboratory-spawned sardine. The established criteria were compared with those used for field collections taken during the Protuguese-Spanish joint Egg Production Method Survey (March-May 1988).

The fraction of mature females with postovulatory follicles, <48 hours old, for the Iberian Peninsula was 0.14 (standard deviation = 0.0122), indicating that the mean interval between spawnings was approximately 7 days.

Seki, M. P. 1993. Trophic relationships of *Ommastrephes bartramii* during winter migrations to subtropical waters north of the Hawaiian Islands. *In* Okutani, T., R. K. O'Dor, and T. Kubodera (eds.), Recent advances in cephalopod fisheries biology, p. 523-529. Tokai University Press, Tokyo.

Ommastrephes bartramii occupy waters in the North Pacific near the Subarctic Boundary during summer and fall where they are targeted by international driftnet fishing fleets. During the winter, *O. bartramii* migrate south to spawn in subtropical waters probably between 25° and 35° N latitude. Diet and trophic relationships were examined for *O. bartramii* during the winter occupation of these subtropical waters. Food composition was determined for stomachs from 42 large (48-57 cm mantle length), mature female *O. bartramii* captured by large (180 mm) mesh driftnet (me ami) during February 12-19, 1991. The bulk of the diet was composed of cephalopods (60.5 percent) and micronektonic fishes (37.7 percent); cannibalism was common. The relationship between winter-migrating *O. bartramii* and the recently developed swordfish, *Xiphias gladius*, longline fishery is also discussed. Squids found among swordfish stomach contents included adult *O. bartramii*, *Thysanoteuthis rhombus*, and *Sthenoteuthis oualaniensis*.

Van Toorenburg, R. A., W. G. Gilmartin, and J. R. Henderson. 1993. Composition of the Hawaiian monk seal at Kure Atoll, 1990. Pac. Sci. 47:211-214.

Population recovery-related management actions have been taken to rebuild the endangered Hawaiian monk seal, *Monachus schauinslandi*, (Matschie) colony at Kure Atoll in the Northwestern Hawaiian Islands since 1981. In 1990, composition of the Kure population was determined by a combination of methods to identify all seals using the atoll. The resident 1990 population included 75 seals, and an increasing trend in the mean annual beach count of seals over the last decade is apparent. Two major changes have occurred in the population since 1985. A shift in the adult sex ratio (males:females), from 2.7:1 to 0.8:1, has developed and appears to be due to both adult male losses and increased recruitment of females. Also, the declining trend in births apparent between 1981 and 1986 has been reversed. These findings suggest cause for optimism for the continued growth of this population.

Wilson, C. D., and G. W. Boehlert. 1993. Population biology of *Gnathophausia longispina* (Mysidacea: Lophogastrida) from a central North Pacific seamount. Mar. Biol. 115:537-543.

Large numbers of the lophogastrid mysid, *Gnathophausia longispina* were discovered in 1984 over Southeast Hancock Seamount on the northern Hawaiian Ridge. Additional specimens were collected from the same area during subsequent surveys in 1985, 1987, and 1988 to obtain new information on the life history of this species. Estimates of growth suggest that *G. longispina* reaches sexual maturity by its second year. Young are brooded by the female for nearly a year and released in late winter-early spring. It is doubtful if *G. longispina* live longer than 2 years or produce more than one brood. Most *G. longispina* are found within 100 meters above the seamount summit. The modal progression of size classes over time indicates that this species is dependent on local processes rather than recruitment from other areas to maintain its population at the seamount.

Approved by Science and Research Director, SWR

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Administrative Reports are strictly for internal use only and are not to be cited or treated as publications.

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Honolulu, Hawaii

Dollar, R. A. 1993. Annual report of the 1992 western Pacific longline fishery. SWFSC Admin. Rep., Honolulu, H-93-12, 25 p.

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